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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°F	degree Fahrenheit	lb/in^2	pound per square inch
ft^3	cubic foot	mg	milligram
ft^3/min	cubic foot per minute	min	minute
ft^3/ton	cubic foot per ton	mL	milliliter
gal	gallon	mm	millimeter
gal/h	gallon per hour	µm	micrometer
gal/min	gallon per minute	pct	percent
L/min	liter per minute	ton/h	ton per hour

USE OF FOAM FOR DUST CONTROL IN MINERALS PROCESSING

By Jon C. Volkwein,[1] Andrew B. Cecala,[2] and Edward D. Thimons[3]

ABSTRACT

The Bureau of Mines conducted a series of tests to evaluate the effectiveness of mixing a compressed-air-generated foam with dried whole-grain silica sand to suppress dust in minerals processing plants. Dust at downstream transfer points was monitored with personal gravimetric samplers and with Real-Time Aerosol Monitors (RAM's) that were connected to strip chart recorders. Results showed dust reductions of 80 to 90 pct on three separate occasions at two different plants. The mechanism by which foam suppresses dust is discussed, as are the constraints on the use of foam, which may include incompatibility of the foam with the mineral product, difficulty in controlling the foam generator, and cost.

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INTRODUCTION

As a part of the 1977 Health and Safety Act for mining, the Bureau of Mines has been conducting respirable dust research in minerals processing. One area of dust control technology that was studied is the use of foam as a dust suppressant. The use of foam for dust control in the mining industry has been tried in the past on underground conveyor systems and mining machines.[4] The resulting dust reductions were only slightly superior to those obtained with conventional water sprays, and since water sprays are simpler and less expensive, foam systems have not been adopted by the industry.

However, recent work indicates that mixing foam with the ore can be very effective in controlling dust. When foam was thoroughly mixed with drill cuttings in the blasthole, dust was reduced by 95 pct; however, when the same type of foam was applied to ore in the mouth of the crusher and not well mixed, only a 27-pct reduction was observed.[5]

Currently, some producers of dried mineral products are considering adding small amounts of moisture to their products to help control dust. The effect of water on materials handling is a primary concern. Foundry experience with industrial sand indicates that 1 to 1.8 pct added moisture could be tolerated for materials handling purposes, and significant dust reduction could result. The use of foam offers dust suppression at even lower rates of water addition.

The objective of this work was to evaluate the ability of a compressed-air-generated foam to suppress dust resulting from the handling of dried whole-grain silica sands.

PROCEDURE

Tests were conducted at several different locations in two mineral processing plants, but the basic test procedure was the same. The foam-generating system consisted of a metering unit that measured the appropriate quantities of water and surfactant and mixed them with air. The resulting aerosol was piped to a generator unit, which made the foam. The foam was then piped to the point where it was added to the sand. The foam and sand were mixed either by a mechanical screw or by passing the material through several transfer points. Dust was measured at transfer points downstream from the foam addition point.

The selection of the sampling locations was very important since the foam, when added to warm sand, created steam that in turn affected the response of the light-scattering instruments used to measure the dust. In all cases, these instruments were located far enough away from the dust source so that the steam condensate was visually dispersed. For measurements near the steam condensate, gravimetric samples were taken.

The light-scattering instruments used in the study were Real-Time Aerosol Monitors (RAM's) manufactured by GCA Corp.[6] They measure the forward scattered light from a dust sample and correlate it to the dust mass. The monitors are sensitive to dust size, shape, and refractive index. If calibrated to a specific dust, the accuracy is ±10 pct that of gravimetric samples. Since response is linear throughout the concentration range, even if an instrument is only roughly calibrated to the dust being measured, it can still serve as a good relative measurement tool. RAM's used for this study were calibrated at the Pittsburgh Research Center, using Supersil silica flour.

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[4]Hiltz, R. H., and J. V. Fried. Using High Expansion Foam To Control Respirable Dust. Min. Congr. J., v. 59, May 1973, pp. 54-60.

Seibel, R. J. Dust Control at a Transfer Point Using Foam and Water Sprays. BuMines TPR 97, 1976, 12 pp.

[5]Page, S. J. Evaluation of the Use of Foam for Dust Control on Face Drills and Crushers. BuMines RI 8595, 1982, 13 pp.

[6]Reference to specific equipment or manufacturers does not imply endorsement by the Bureau of Mines.

Gravimetric samples of respirable dust were taken on MSA FWS-B field cassettes. Samples were taken by Bureau and plant personnel using Du Pont PA 2000 flow-controlled pumps and MSA model G personal sampling pumps, respectively. Filters were preweighed and postweighed under constant temperature and humidity conditions. All pumps were operated at 1.7 L/min; samples were taken through 10-mm Dorr-Oliver nylon cyclone classifiers. A recording vane anemometer was used to keep track of wind velocity and direction, so that the data could be normalized for changing airflow or direction.

Size distributions of the airborne fraction of dust were taken at one location. Size distributions of both treated and untreated sand were measured with an Andersen eight-stage cascade impactor. Fiberglass substrates in which each size fraction of dust was collected were preweighed and postweighed under controlled conditions.

Dust was measured from sand that was treated in one of two ways: by the batch or during real time. Batch treatment of sand consisted of adding foam to the sand and depositing the sand in a bin. As the treated bin was emptied into hopper cars, resulting dust levels were measured. The same procedure was used for untreated sand. The real-time treatment of sand involved measuring the dust concentrations emanating from a grizzly or transfer point immediately after foam was added to the sand.

DESCRIPTION OF TESTS

Plant A was a large industrial sand plant producing chiefly glass sand. Three types of tests were conducted at this plant:

1. A preliminary test series measured the effectiveness of foam added to free-falling sand, which then moved through three transfer points, entered a bulk storage bin, and then was loaded into a railroad hopper car (fig. 1). The sand was sized 30-mesh glass sand at temperatures of about 120° F. Gravimetric samples were taken at the first and third transfer points and at the railroad hopper car bulk loadout. RAM samples were measured downwind from the bulk loadout and corrected for background dust concentrations and changing airflows.

2. This test series was a repeat of the first, using different amounts of foam. Dust concentrations were measured only at the railroad loadout. Airborne dust size distributions were also measured at the loadout.

3. In these tests (fig. 2), foam was added at the end of the plant dryer and mixed in a screw conveyor that had been modified to better mix the foam into the sand. The sand at this point was cleaned run-of-mine sand at a temperature of 190° F. Gravimetric samples were taken at three transfer points. RAM samples were taken intermittently at all but one transfer point.

Plant B was a smaller industrial sand plant producing a variety of sand products. Tests at this plant used various quantities of foam, water, and water plus

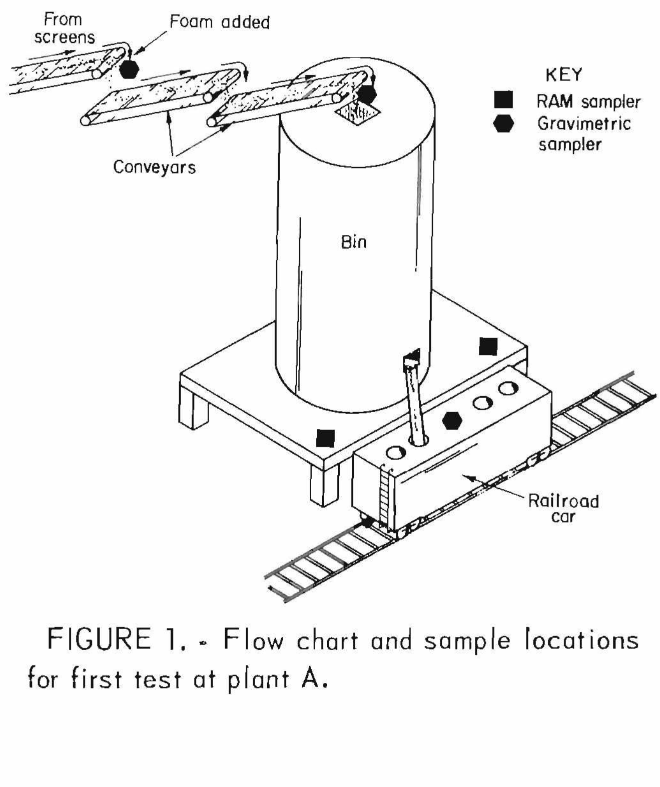

FIGURE 1. - Flow chart and sample locations for first test at plant A.

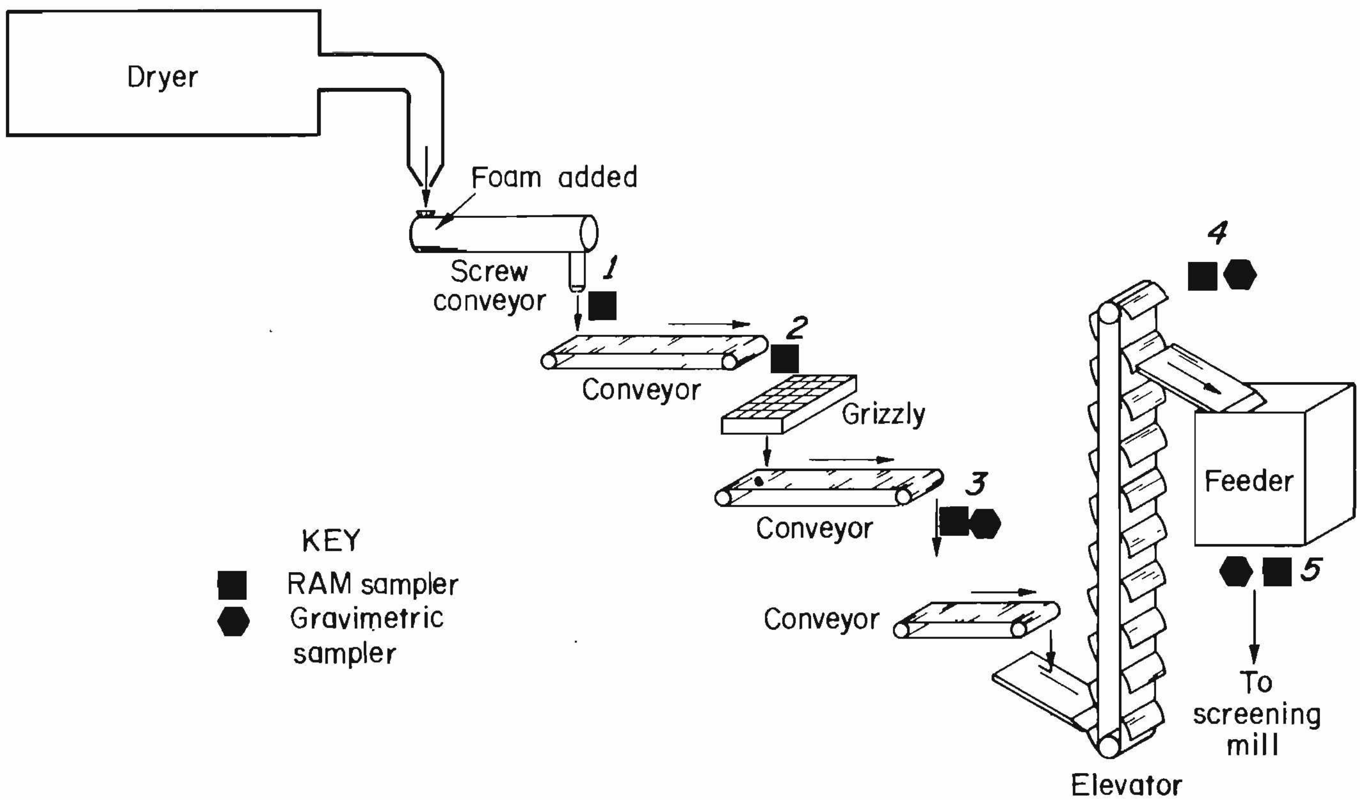

FIGURE 2. - Flow chart and sample locations for third test at plant A. Sample location numbers are referenced in table A-1 in the appendix.

foaming agent (not generated into foam). Either water or foaming agent was added to dried run-of-mine sand and mixed in an inclined screw conveyor (fig. 3). The sand then passed over a grizzly to a bucket elevator. The top of the grizzly was removed, and dust was measured downwind from this point. For each of the tests, the resulting dust levels were measured for about 10 min wet and 10 min dry. Only periods of full production with constant conditions were compared.

RESULTS

The results of the first series of tests at plant A showed that as sand moved and was mixed with the foam from transfer point to transfer point, the dust suppression effectiveness of the foam increased. Table 1 shows the

TABLE 1. - Increasing dust reduction as foam is mixed with sand from one transfer point to the next

(Test 1 at plant A)

Location	Condition	Dust measurement, 4 filters		Dust reduction, pct
		Average, mg	Standard deviation	
1st transfer point	No foam..	7.41	1.83	
	Foam.....	5.95	.87	19.7
3rd transfer point	No foam..	5.59	.10	
	Foam.....	3.76	.05	32.7
Bulk loadout......	No foam..	6.69	.29	
	Foam.....	2.46	.10	65.3

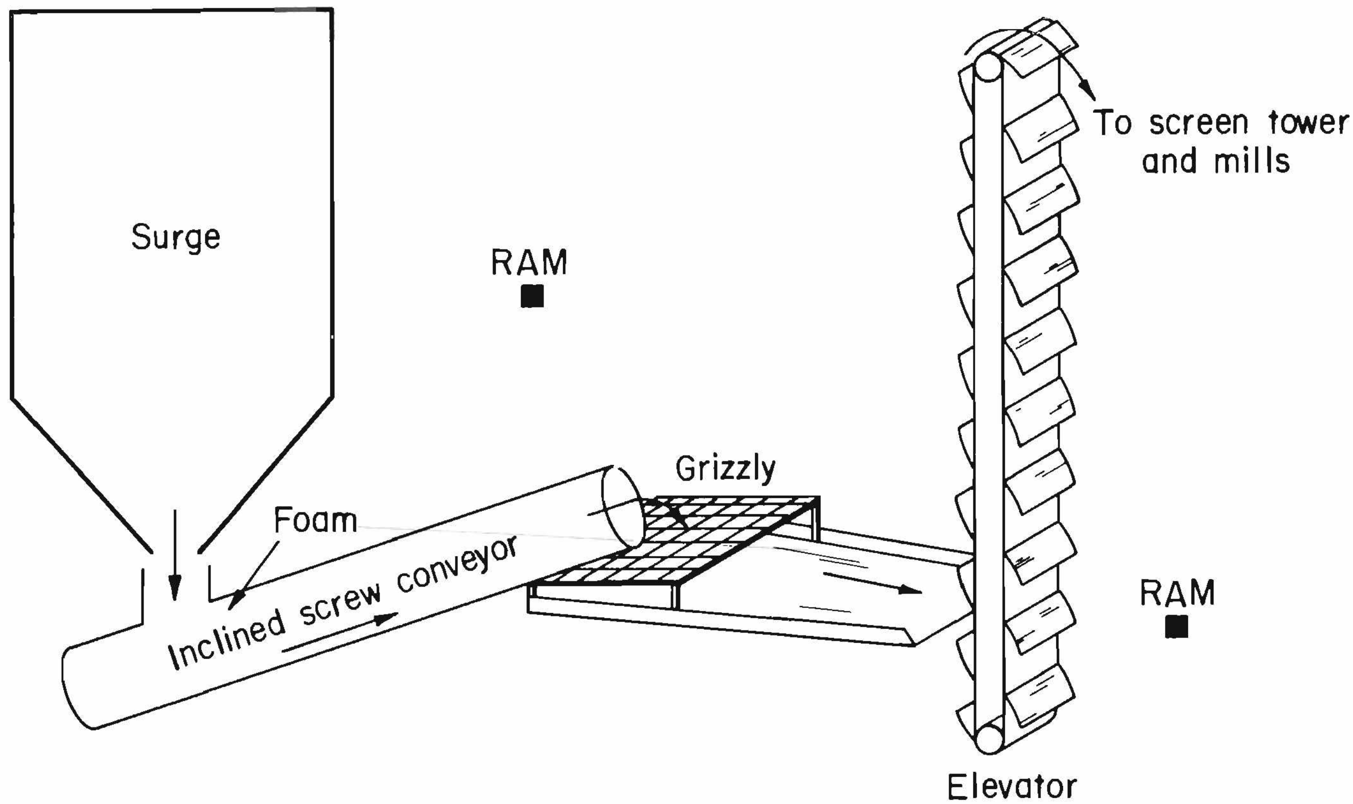

FIGURE 3. - Flow chart and sample locations at plant B.

gravimetric data for respirable dust. RAM measurements taken the same day at the rail loadout showed a reduction in respirable dust of 81 pct. The previous day, the RAM had shown an 82-pct reduction (no gravimetrics were run that day).

The second series of tests at plant A attempted to determine the most economical amount of foam needed to achieve adequate dust suppression. Although the foam equipment was operated by the manufacturer, it was difficult to control the quantities of foam made by the machine. Gages installed in-line to measure water, air, and surfactant flow rates pulsed too violently to obtain readings. As a result, only two batch runs were made at two different foam flow rates. The aerosol pressure (pressure of air, water, and surfactant going to the foamer) was used to determine the flow rates. These pressures were 36 lb/in^2 the first day, and 18 lb/in^2 the second.

Results for the second batch tests at plant A showed very good dust suppression at the rail loadout, resulting from the addition of foam. A visual observation of the dust reduction is shown in the photographs in figure 4. Dust reductions of 97 pct the first day and 93 pct the second day were measured with the RAM. Gravimetric samplers run simultaneously showed dust reductions of 99 and 96 pct, respectively.

The airborne dust size distribution was measured on the second day at plant A. Figure 5 shows that the dust from both treated and untreated sand was about the same size, with a median aerodynamic diameter of about 10 µm and a geometric standard deviation of 2.7. The *total* dust suppression efficiency of the foam, determined by the *total* mass collected on the Andersen impactor, was 90 pct. This is about the same efficiency as for the *respirable* fractions measured gravimetrically and with the RAM.

Attempts were also made to determine the most economical amount of foam to achieve adequate dust suppression at

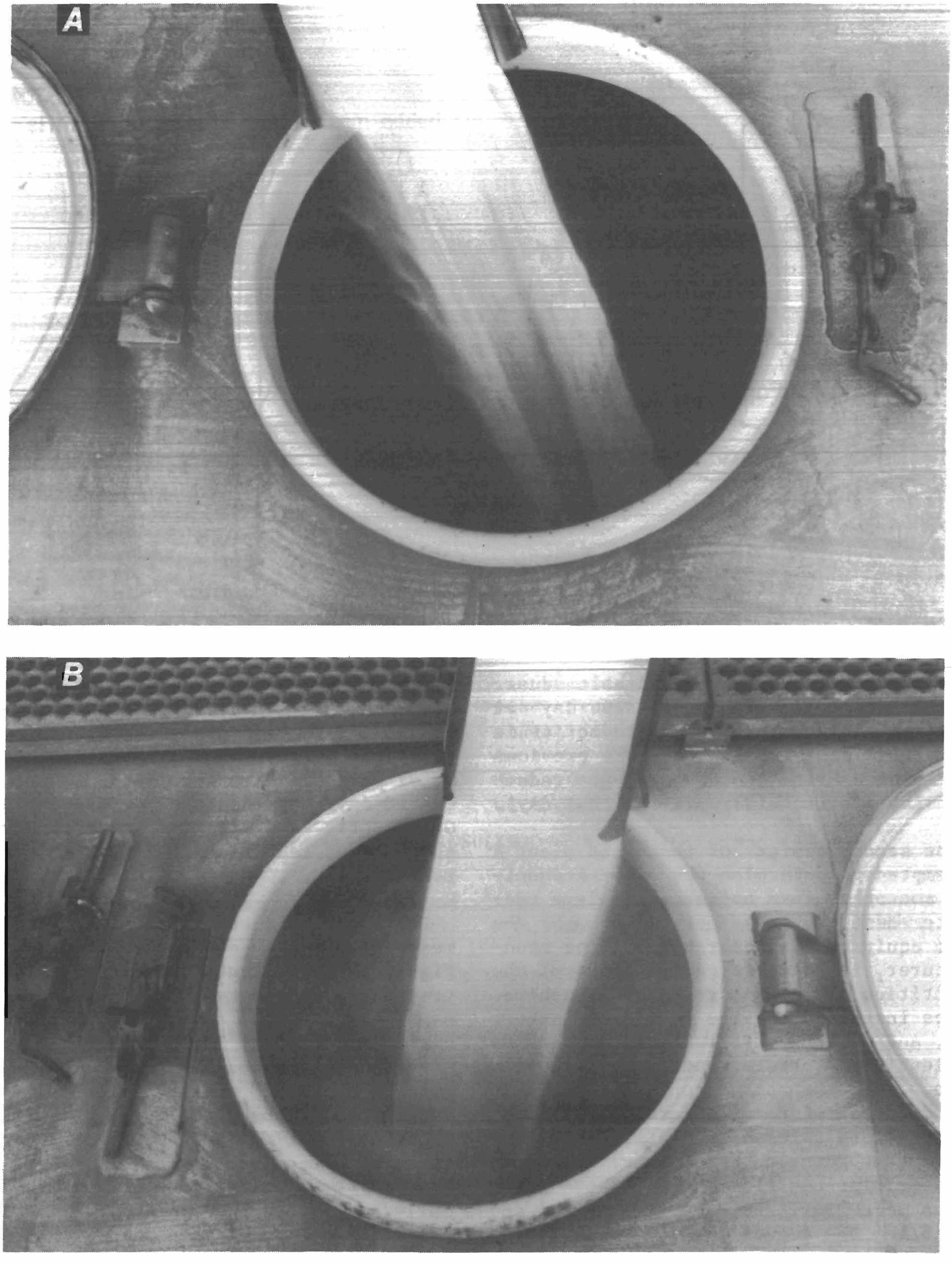

FIGURE 4. - Visual difference in dust generation during loading of foam-treated sand (*A*) and untreated sand (*B*).

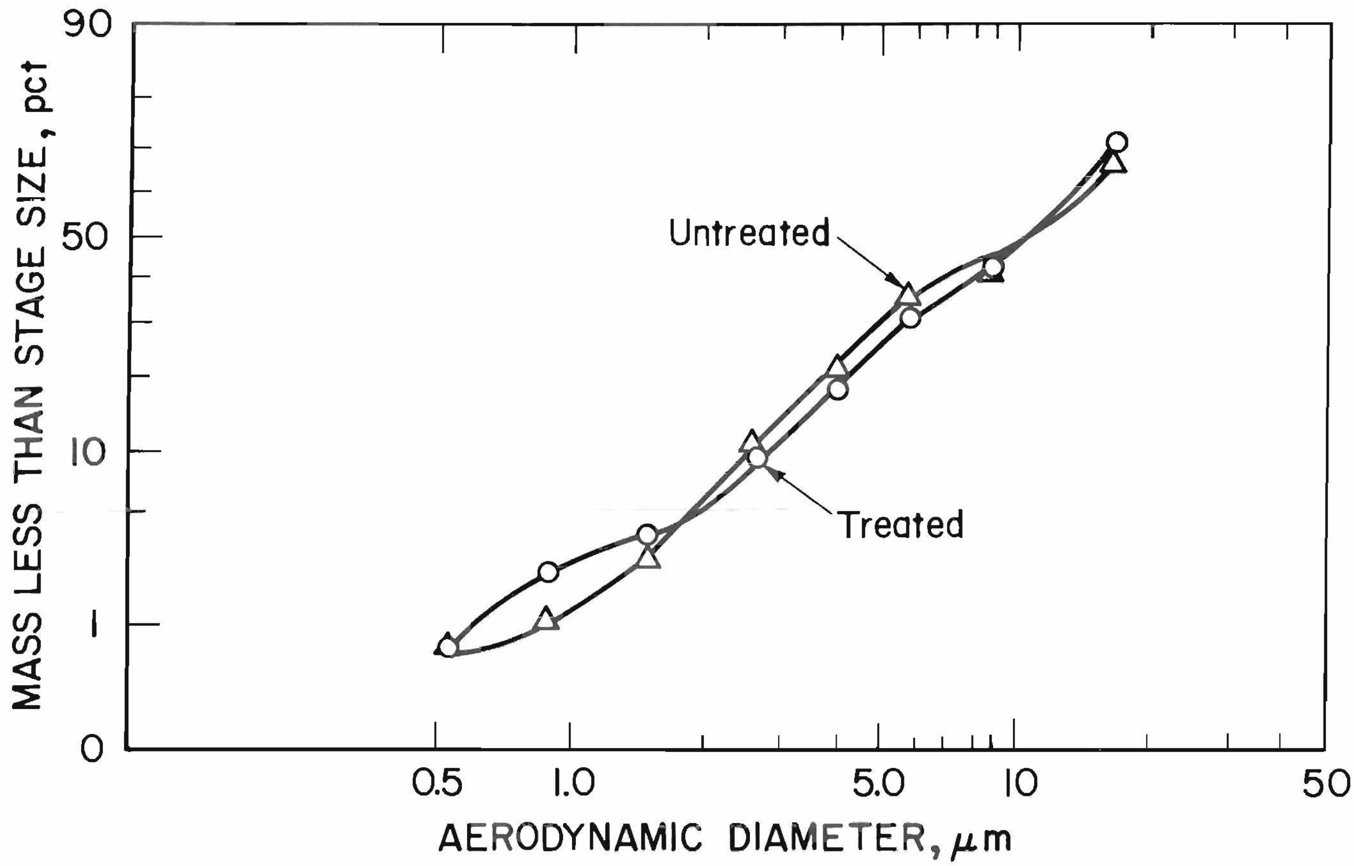

FIGURE 5. - Aerodynamic size distribution of foam-treated and untreated dust.

plant B. Again it was difficult to control the amount and quality of foam produced. Many variables changed from one flow rate to another, rather than changing one at a time. Thus, when the foam line was restricted to reduce flow, the foam became wetter, resulting in fewer bubbles, more water and surfactant, and a reduction of the expansion ratio of the foam.

Generally, for a constant tonnage of materials, the more cubic feet of foam added, the greater the dust reduction. Table 2 shows the respirable dust reductions and a few of the parameters that

TABLE 2. - Foam parameters and respirable dust reduction at plant B

Test	Amount of foam		Liquid flow rate, gal/min	Expansion factor[1]	Dust reduction, pct
	Volume, ft^3/min	Rate, ft^3/ton sand			
1	[e]1.48	10.5	0.38	NA	92
2	[e]1.48	10.5	.38	NA	91
3	1.20	8.2	.34	3.53	79
4	1.20	8.2	.34	3.53	68
5	1.10	7.5	.20	5.50	68
6	.70	4.8	NA	NA	0
7	.70	4.8	.18	3.89	0
8	.38	2.6	.13	2.92	0
9	.38	2.6	.13	2.92	0

[e]Estimated. NA Not available.
[1]Foam (ft^3/min)/liquid (gal/min).

were measured at plant B. Between 4.8 and 7.5 ft^3 of foam per ton of material was required before dust reductions were evident.

Figure 6 is an example of the RAM-generated strip chart of the dust levels used to calculate the dust reductions in table 2. When possible, dust levels both before and after foam treatment were averaged and used as the baseline for determining the dust reductions. In figure 6, the level of reduction shown is 91 pct.

Results from plant B also show that water expanded into foam was more effective than the equivalent amount of water, or water mixed with the foaming surfactant (table 3). Almost doubling the waterflow rate increased dust suppression by only 12 pct. The foaming surfactant did not improve the ability of water mixed into the product to suppress dust. However, when approximately the same mixture of surfactant in water was expanded into foam, the dust suppression increased from 54 to 73 pct. Further addition of foam boosted the reduction to over 90 pct, without adversely affecting the materials handling of the product.

Based on the success of the above tests, plant A decided to treat all product material with foam at the dryer discharge, to suppress dust throughout the plant (test 3, shown in figure 2). However, little or no dust suppression was achieved. The appendix shows the foam

TABLE 3. - Type of water added and resulting dust reduction

Test condition	Volume of liquid, mL	Dust reduction, pct
Foam............	1,420	[1]91
	1,300	[1]73
	764	68
Water...........	757	46
	1,324	58
Water with 1.5 pct surfactant.	1,324	54
Water with 2.5 pct surfactant.	1,324	54

[1]Average reduction.

parameters that were varied and all the locations where dust levels were measured. Neither Bureau nor plant personnel were able to measure any significant dust reductions. One possible reason why no significant dust reductions were observed is that the high temperature of the sand leaving the fluid bed dryer (190°±10° F) may have evaporated the water. In fact, an abundance of steam was observed along the first conveyor belt.

Further testing in the laboratory of the effect of hot sand on the evaporation rate showed that at a sand temperature of 210° F, over half of the added moisture evaporated in the first 2 min (fig. 7). Sand in this experiment was on an open plate. A higher evaporation rate would be expected for sand passing through a transfer point since the exposed surface area is greater.

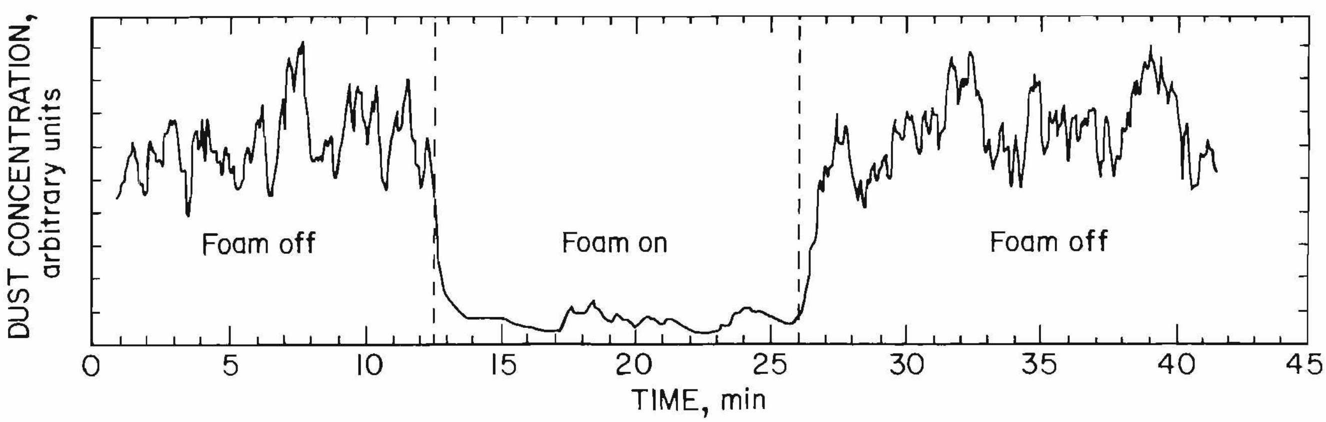

FIGURE 6. - RAM strip chart recording of one test at plant B.

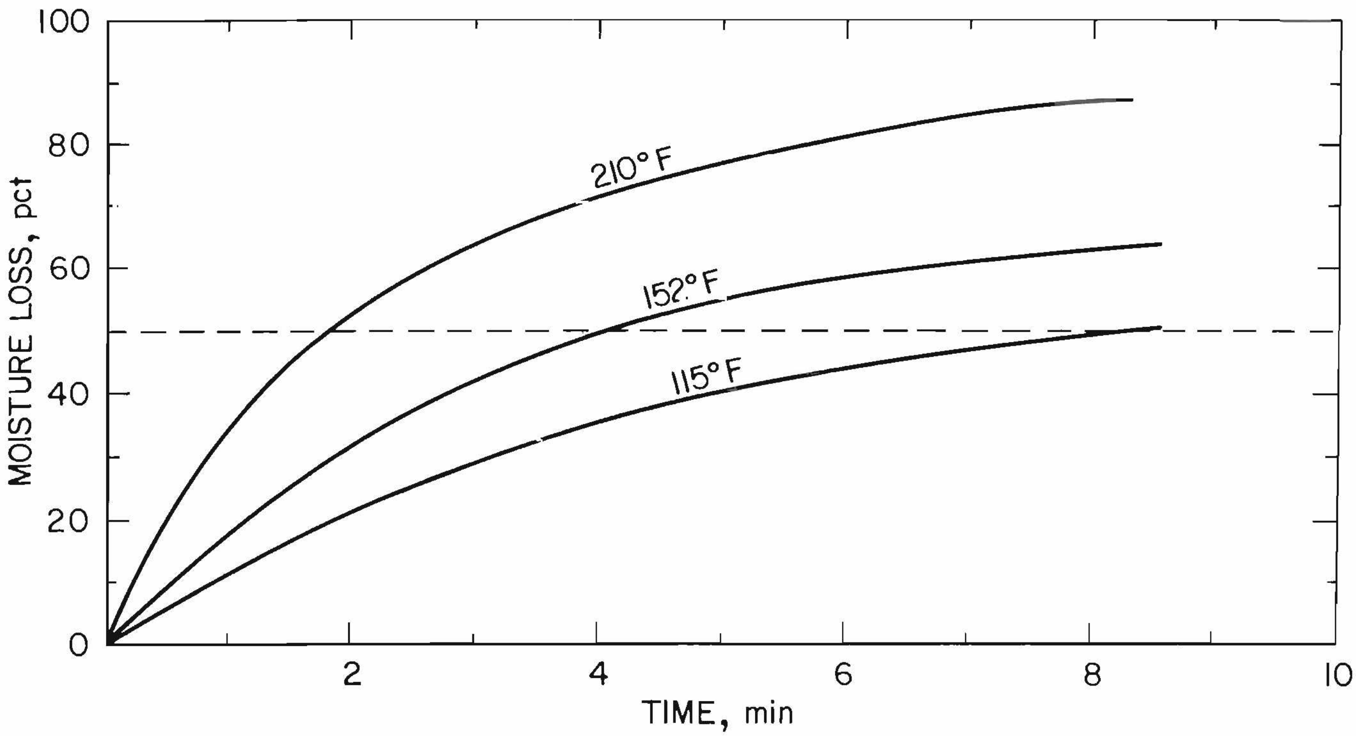

FIGURE 7. - Moisture loss of hot sand versus time. Dashed line indicates 50 pct.

DISCUSSION

The results indicate that foam can be very effective in suppressing dust, when applied under the right conditions. Foam can even be used in "dry" materials since the added moisture is distributed over a large area. Complete mixing of the foam with the product material is probably the most important element for good dust suppression; it also eliminates materials handling problems.

Another demonstration of foam dust suppression capabilities was shown at a joint Government-industry meeting by one of the industrial representatives. Two jars of 400-mesh silica flour were shaken and the tops removed; one jar was treated with foam, the other was not. Visible dust rose from the untreated jar, none from the treated jar. Although the demonstration was interesting, of more importance was the subsequent observation that after several months of demonstrations the treated material became as dusty as the untreated. Most likely the water evaporated, and it was the additional moisture and not the surfactant that caused the foam to suppress dust.

Evidence of the role of water in dust suppression by foam was shown by the lack of dust suppression when the hot sand from the dryer discharge was treated. Heat should not appreciably affect the surfactant, but it does affect the water, which evaporates (some of the solvent used to liquify the surfactant may also evaporate). Addition of water, however, is not the only reason why foam suppresses dust. When water alone was mixed with product materials, dust suppressions of about 50 pct were recorded, and simply adding the foaming surfactant to water did not appreciably increase the dust suppression. However, the equivalant amount of water-surfactant expanded into foam reduced dust 73 pct. Apparently the ability of foam to suppress dust is not purely a function of adding moisture nor a particular property of the surfactant, but rather a function of the expansion of the liquid to provide a greater surface area for the moisture and hence greater contact with the dust.

The dust suppression ability of foam does not appear to be size selective. One theory of the foam's superior dust suppression ability was that the micrometer-size foam bubbles selectively collapse around the micrometer-size dust particles, thus reducing the fine fraction of dust more than the coarse. However, it seems unlikely that a foam bubble would be selective about where it breaks, and indeed there is no real difference in the airborne size distributions of the dust produced from dry or foam-treated sand.

Before foam can be considered for use as a dust control technique, the following limitations must be recognized:

1. The compatibility of the foaming surfactant with the product's end uses must be considered. Ultrapure grades of certain products cannot tolerate even a few parts per million of surfactant.

2. Foam generators must be easy to control and regulate. The foam generators observed in this work were very difficult to control. This is especially critical if minimum moisture levels on the order of a few tenths of a percent are to be maintained.

3. Evaporation will reduce the effectiveness of the treatment. This is most likely to be a problem at high product temperatures.

4. Foam is relatively expensive. According to the data in the appendix, the average amount of surfactant per ton of sand treated was 0.012 gal. At a surfactant cost of $7.25 per gallon, the cost to treat each ton of sand is 9 cents (exclusive of capital and power cost). Of course, depending on usage, this number can range from a low of 4 cents to a high of 20 cents per ton. A similar figure was quoted for testing done at a surface coal plant.

CONCLUSION

Foam can be an excellent dust suppressant when well mixed with cool sand. Dust reductions of 80 to 90 pct were obtained on three separate occasions at two different sand plants. Both respirable and total dust were equally suppressed. Compatibility with the mineral product, control of the foam generator, and cost are the three main limiting factors to the wider use of foam in minerals processing.

The exact mechanism by which foam suppresses dust is not well understood. Evidence seems to show that not only the addition of moisture but also the exposed surface area is important. Further work is needed on why foam works and on the most economical amount of foam to use.

APPENDIX

TABLE A-1. - Foam parameters and dust reduction data at plant A

(Test series 3)

Test	Test duration, min	Foam parameters: Water, gal/h	Foam parameters: Surfactant, gal/h	Foam parameters: Cam setting[1]	Sand: ton/h	Sand: Moisture added, pct[2]	Dust sampler type	Sample location: No.[3]	Sample location: Description	Dust reduction, pct
1.....	15	52	2.8	2-1/2	176	0.13	None.......	-	NA................	NA
2.....	15	68	1.2	2-1/2	176	.16	RAM........	1	Under screw conveyor	8
3.....	15	72	1.0	2-1/2	180	.17	RAM........	1	...do..............	33
4.....	13	139	1.2	2-1/2	173	.34	RAM........	4	Top of elevator.....	17
							RAM........	1	Under screw conveyor	0
5.....	15	48	2.6	3-1/2	192	.10	RAM........	1	...do..............	0
6.....	15	56	2.0	3-1/2	168	.14	RAM........	4	Top of elevator.....	0
7.....	15	72	3.2	3-1/2	180	.17	None.......	-	NA................	NA
8.....	11	87	2.7	3-1/2	185	.20	RAM........	4	Top of elevator.....	12
9.....	30	64	1.6	1-3/4	178	.15	RAM........	3	Chute to conveyor...	0
10.....	15	98	1.2	1-3/4	186	.22	Gravimetric	4	Top of elevator.....	0
							RAM........	3	Chute to conveyor...	27
							Gravimetric	4	Top of elevator.....	11
11.....	15	64	2.8	2-1/2	192	.14	RAM........	3	Chute to conveyor...	9
12.....	15	52	2.2	2-1/2	212	.10	RAM........	3	...do..............	0
13.....	15	92	1.4	1-3/4	212	.18	RAM........	3	...do..............	23
14.....	15	72	1.4	1-3/4	176	.17	RAM........	5	Feeder.............	0
							RAM........	3	Chute to conveyor...	0
							RAM........	5	Feeder.............	0
15.....	15	80	4.4	5	196	.17	Gravimetric	5	...do..............	7
							RAM........	3	Chute to conveyor...	0
							RAM........	5	Feeder.............	3
16.....	15	124	4.2	5	192	.27	Gravimetric	5	...do..............	0
							RAM........	3	Chute to conveyor...	0
							Gravimetric	5	Feeder.............	0

NA Not available.
[1]Cam setting increase increases surfactant volume.
[2](Pounds water/pounds sand) × 100.
[3]Locations are shown on figure 2 in the main text.

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